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I, Ian McBride, MA(Edin)., MITI., declare

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2. That I am well acquainted with the English and German languages.
3. That the attached is a true translation into the English language of International Patent Application No. PCT/EP99/09250.
4. That all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the patent application in the United States of America or any patent issuing thereon.

Signed, this 24th day of May 2001



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09/869407-062204

Flat storage element for an X-ray image

The invention relates to a flat storage element for an X-ray image according to the preamble of claim 1.

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Storage elements of this kind are obtainable commercially as so-called storage films.

10 With such storage films the storage layer formed by storage particles and a binding agent matrix is optically inhomogeneous, and there occurs as a result of said inhomogeneities a scattering of the activating light, which is used for reading out the latent image, and also a scattering of the measuring light read out. The resolution
15 of the storage element is consequently influenced disadvantageously.

The above-mentioned scatter effects are the stronger the smaller the storage particles are. Small storage particles
20 are conversely advantageous, however, with respect to high resolution of the storage element.

There is therefore to be created by the present invention a storage element according to the preamble of claim 1 which
25 is optically homogeneous, so that no scattering of activating light and measuring light takes place in the storage layer.

This object is achieved according to the invention by a
30 storage element with the features given in claim 1.

With the storage element according to the invention the refractive indices of the storage particles on the one hand

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and of the binding agent on the other are adjusted to one another. The optical inner boundary surfaces at which the scattering of activating light and measuring light takes place therefore disappear. The whole of the storage layer
5 behaves optically like a single-component material.

An improved resolution is thus obtained with the storage element according to the invention.

10 Advantageous developments of the invention are given in sub-claims.

If according to claim 2 different salts crystallising together are used for the storage particles, the refractive
15 index may be adjusted simply within very wide limits. It is possible by corresponding variation of the ratio in which the two salts are provided to cover a wide range of binding agent refractive indices, to attain exactly the refractive index of a predetermined binding agent.

20 A refractive index of preferably between 1.4 and 1.6 is selected for the binding agent according to claim 6. A large number of different salt compositions is then available with which said range of the refractive index may
25 be realised, so that a selection may be made from said large number in terms of other parameters to be included, e.g. the size of the particular unit cell of the salt which influences the preferred excitation wavelength of the colour centres formed.

30 The development of the invention according to claim 7 also prevents small residual scattering of the light, such as would be caused by an anisotropic material.

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The development of the invention according to claim 8 prevents a deterioration in the resolution, such as would be obtained by reflections on the front boundary surface of the storage layer viewed in the direction of motion of the light.

With the development of the invention according to claim 9, reflections of activating light on the rear side of the storage layer are eliminated. A further improved spatial resolution of the X-ray image read out is thereby obtained.

With a storage element according to claim 10 the yield of fluorescent light is improved, since the light radiated into the rear half-space is reflected towards the front side. The sensitivity of the storage film is improved by a factor of 2 in this way.

The development of the invention according to claim 11 is of advantage in terms of minimising the radiation load on a patient whose teeth are X-rayed with a storage element held behind the jaw.

The development of the invention according to claim 12 is of advantage in terms of a simple handling of the storage element. The whole of the storage element may thus also be bent without fold formation

A storage element as given in claim 13 may be adapted effectively to curved surfaces, e.g. the curvature of a jaw.

The method given in claim 14 ensures that the binding agent also fits exactly positively in microscopic terms around the storage particles. No small air inclusions or cavities therefore arise, which in turn could again represent
 5 scatter centres.

The invention will be explained in detail below from embodiments with reference to the drawing. In the latter:

10 Figure 1 shows an enlarged section through a bendable storage element for use in the X-raying of teeth, which is placed perpendicular to the plane of the storage element,

15 Figure 2 shows a view onto the storage element, such as is obtained if the refractive indices of storage particles and binding agents of the storage element are different,

20 Figure 3 shows a similar view to Fig. 2, such as is obtained if the refractive indices of storage particles and binding agents are equal and

Figure 4 shows a graphic representation of the refractive
 25 indices of selected transparent plastics materials.

Fig. 1 shows a section through a flexible storage element 10 which may be used instead of a conventional
 30 tooth film during the x-raying of teeth. The storage element has a central storage layer 12 whose composition will be described in even greater detail below, a front anti-reflection coating 14, a rear reflecting/absorbing

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solvent etc.. The lead film 18 may be connected to the rear side of the absorbing layer 16 by a thin layer of adhesive.

The storage layer 12 comprises a large number of storage particles 20 which are shown simplified in the drawing as small spheres, but in reality have an irregular geometry such as is obtained by the fine grinding of salt. The storage particles 20 are held together by a transparent binding agent 22 which is preferably a transparent organic binding agent that is selected from the group given in Table 1 below:

Table 1

15	Class	Representative	Abbreviation
	Polyolefins	Polyethylene	PE
		Polypropylene	PP
		special polyolefins	PB, PMP
20	Vinyl chloride polymers	Polyvinyl chloride, rigid	PVC-U
		Polyvinyl chloride, flexible	PVC-P
	Styrene polymers	Polystyrene	PS
		Styrene-butadiene	SB
		Styrene-acrylonitrile	SAN
25		Acrylonitrile-butadiene-styrene	ABS
		SAN with acrylic elastomer	ASA
	Cellulose esters	Cellulose ester	CA, CP, CAB
	Polymethyl methacrylate	Polymethyl methacrylate	PMMA
30	Polyamides	Polyamide 6	PA6
		Polyamide 66	PA66
		Polyamide 11, polyamide 12	PA11, PA12
		Polyamide amorphous	PA6-3-T

	Polyacetals	Polyoxymethylene	POM
	Linear polyesters	Polyethylene terephthalate	PETP
		Polybutylene terephthalate	PBTP
	Polycarbonate	Polycarbonate	PC
5	Polyphenylene oxide	Polyphenylene oxide modified	PPO
	Special plastics	Polysulphones	PSU, PES
		Polyphenylene sulphide	PPS
		Polyimides	PI
		Silicone resin materials	SI
10	Fluorine-containing polymers	Polytetrafluoroethylene	PTEE
		Fluorine-containing thermoplastics	FEP, PFA
			ETFE, PVDF, PVF
	Phenoplastics	Phenoplastics	PF
15	Aminoplastics	Melamine resins	MF
		Urea resins	UF
	Unsaturated polyesters	Unsaturated polyesters	UP
	Epoxy resins	Epoxy resins	EP

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The refractive index for the above-mentioned plastics for visible light is shown in Figure 4 of the drawing.

In Figure 4 the binding agents which are crystal clear are provided additionally with a star.

The storage particles 20 consist of a material in which metastable excited states are generated by interaction with impinging X-ray beams. Said metastable states have typically a life of at least a few minutes. Because activating light is irradiated into the absorption bands of said metastable states, an unstable excited state may be

obtained, which then passes into the ground state with the emission of fluorescent light.

Suitable metastable states are based in practice on defects in the crystal lattice, which are formed inter alia by lattice defects or else impurity atoms. Thus in alkali halide crystals, for example, anion defects may store electrons metastably, which are accelerated during the X-ray absorption, and form so-called colour centres. Holes may form metastable states in said metals in V-centres or on impurity atoms.

The capacity to generate a latent X-ray image in the storage layer 12 is attributable to the colour centres of the storage particles 20. The refractive index which the activating light sees or the fluorescent light triggered by the latter sees, depends first and foremost on the macroscopic refracting angle index of the storage particles 20 or of the binding agent 22.

Because the two refractive indexes are adjusted to one another, the scattering of the activating light and of the fluorescent light, which is generated by emptying of a metastable state with the use of activating light, is prevented. The fluorescent light detected with a photodetector, which forms part of a reproduction device for latent X-ray beams, may therefore be correlated precisely with the radiated point-by-point read-out surface of the storage element.

The adjustment of the refractive indices of storage particles 20 and binding agent 22 may in the case of alkali halides be produced within wide limits by specific choice

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of the basic material for storage particles 20. Table 2 below gives an overview of the refractive indices of pure alkali halides:

5 Table 2

	F	Cl	Br	I
Li	1.3915	1.662	1.784	1.955 (3)
Na	1.327	1.5442	1.6412	1.7745
10 K	1.363	1.490	1.559	1.677
Rb	1.398	1.493	1.5530	1.6474
Cs	1.478(5)	1.6418	1.6984	1.7676

Since the alkali halides are all miscible with one another
 15 over a wide range (same crystal class), the refractive index of the mixed crystal obtained may be varied within wide limits by the mixing of two different salts. If, for example, a mixed crystal of KCl and RbBr is considered and the composition of the mixed crystal is written as
 20 $K_xRb_{1-x}Cl_yBr_{1-y}$, where x and y each lie in the range between 0 and 1, there is obtained with varying of x and y between 0 and 1 a range of adjustment of the refractive index of 1.490 to 1.559.

25 If defects are formed in said mixed crystal, e.g. by the addition of 0.1 mol % Tl^+ , because of the small concentration, the doping has only a small effect on the refractive index of the mixed crystal of not more than 0.1%.

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A second means of securing the adjustment of the refractive index is the selection of the binding agent, wherein different refractive indices are obtained for different

binding agents in accordance with the nature of the monomers. For some of the binding agents the refractive index may again be varied within a range by influencing the chain length and the cross-linking. This is discernible
5 from the representation of the refractive index for various plastics materials which is reproduced in Figure 4.

Typically the diameter of the storage particles comes to about 10 μm , the thickness of the storage layer to 100 μm .

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It is further seen from Figure 4 that glasses are also considered as binding agents, wherein the refractive index may be adjusted over a greater range by means of the composition of the glasses.

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In terms of the robustness of the storage element and in terms of a manufacturability of the storage elements at not excessively high temperatures, organic binding agents are preferred.

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The anti-reflection coating is produced in the conventional manner, e.g. by the evaporation of material with suitable refractive index and in suitable thickness. The absorbing layer 16 is manufactured of a material absorbing the laser
25 light used for the reading out of the latent image and may likewise be vapour-deposited or printed on as ink.

In Figure 2 the various storage particles 20 appear as phase objects. There is therefore obtained there
30 microscopically the same image as that of glass beads placed in a glass of water.

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Because the refractive index of storage particles 20 and binding agent 22 are adjusted to one another, said phase objects disappear and there is obtained for the storage element the appearance reproduced in Figure 3: the latter
5 behaves for the laser light used for the reading out of the latent X-ray image like homogeneous slab glass.

As already mentioned above, the storage particles have in reality the shape of ground material with small bevels. In
10 order also to obtain an embedding of the storage particles in the binding agent which is free of microscopic cavities, the following procedure is adopted during the production of the storage layer 12:

15 Binding agent 22 is prepared in the liquid state. The storage particles 20 are distributed homogeneously in the liquid binding agent 22. The material obtained in this way is brushed out to a thin layer and the binding agent is then cured, so that a storage film with corresponding
20 thickness is obtained.

The binding agent is further preferably prepared in the highly liquid state, to which end it is diluted and/or heated.